CHAPTER 13

PRACTICE EXERCISES

SECTION I MULTIPLE CHOICE

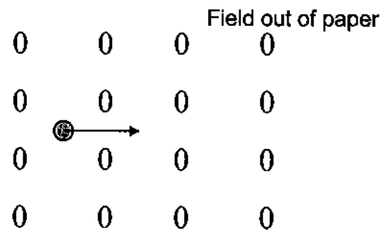

Figure 12

1. An electron is moving to the right in a region where a uniform magnetic field is directed out of the paper. The direction of the force on the electron will be

   (A) up (B) down (C) left (D) right (E) into paper

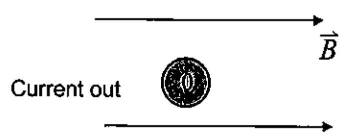

Figure 13

2. A wire carries electric current out of the paper as shown in the figure. With a magnetic field directed to the right, the force on the wire will be directed

   (A) up (B) down (C) left (D) right (E) into paper

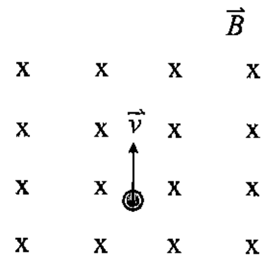

Figure 14

3. A positive charge q is moving with velocity $\vec{v}$ perpendicular to a magnetic field $\vec{B}$ shown into the paper in the figure. The magnitude and direction of the electric field that will allow the charge to pass undeflected are

	Magnitude	Direction
(A)	qvB	left
(B)	$\frac{B}{v}$	left
(C)	Bv	right
(D)	Bv	left
(E)	Bv	out of paper

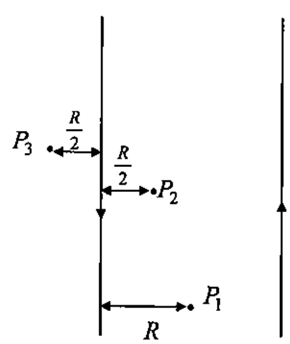

Figure 15

4. Two long parallel wires carry equal currents in opposite directions. A proton moving at a speed of 2×10^5 m/s would experience the maximum force

(A) at P_1 moving left (B) at P_2 moving left (C) at P_3 moving left
(D) at P_2 moving into paper (E) at P_1 moving into paper

5. An electron moving with a speed of 2×10^6 m/s perpendicular to a uniform magnetic field of 10^{-3} T will execute one revolution of a circular path in a time most nearly

(A) 1 s (B) 10^{-6} s (C) 10^{-8} s (D) 10^{-10} s (E) 10^{-15} s

6. Two long parallel wires separated by a distance D carry currents I_1 and I_2. To increase the force exerted by each wire on the other by a factor of 2, you could
   I. double each current and double the separation
   II. double one current only and keep the separation the same
   III. keep the currents the same and halve the separation

   (A) I and II only (B) I and III only (C) II and III only
   (D) I, II, and III (E) II only

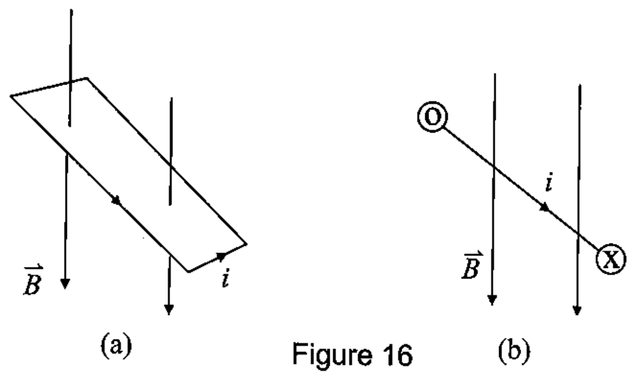

Figure 16

7. A rectangular loop carrying current i is positioned in a uniform magnetic field as shown in the figure. Referring to b where the loop is shown from the side, the loop will

   (A) move down as a unit (B) move up as a unit (C) remain stationary
   (D) rotate clockwise (E) rotate counterclockwise

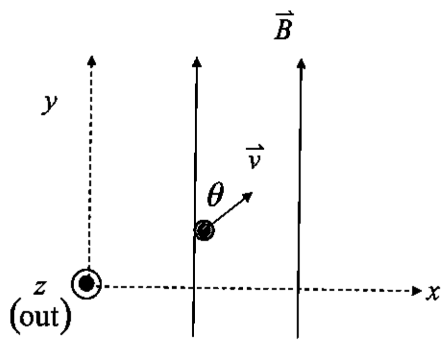

Figure 17

8. A positive charge currently has a velocity in the x-y plane, making an angle θ with respect to a uniform magnetic field directed along the $+y$-axis. The subsequent motion of the charge could best be described as

   (A) circular motion in the x-y plane
   (B) uniform motion
   (C) circular motion in the x-z plane
   (D) helical motion with axis parallel to the z-axis
   (E) helical motion with axis parallel to the y-axis

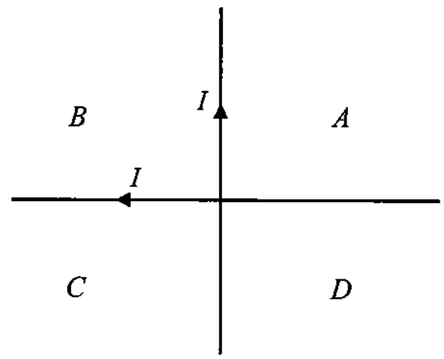

Figure 18

9. Two wires carrying equal currents are perpendicular to each other as shown in the figure. The largest magnitude of magnetic field pointing out of the paper is in region

(A) A (B) B (C) C (D) D (E) field does not point out in any of these regions

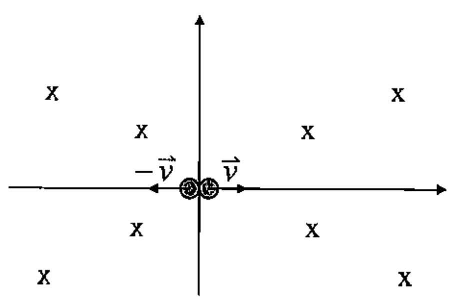

Figure 19

10. An elementary particle process creates two equal but oppositely charged (q), equal mass m particles at the origin in a region where a uniform magnetic field $\vec{B}$ is directed into the paper. At the instant they are created they have equal but opposite velocities. The two particles will collide after a time

(A) $\frac{2\pi m}{qB}$ (B) $\frac{\pi m}{qB}$ (C) $\frac{\pi m}{2qB}$ (D) $\frac{3\pi m}{2qB}$ (E) They do not collide.

CHAPTER 13

PRACTICE EXERCISES

SECTION II FREE RESPONSE

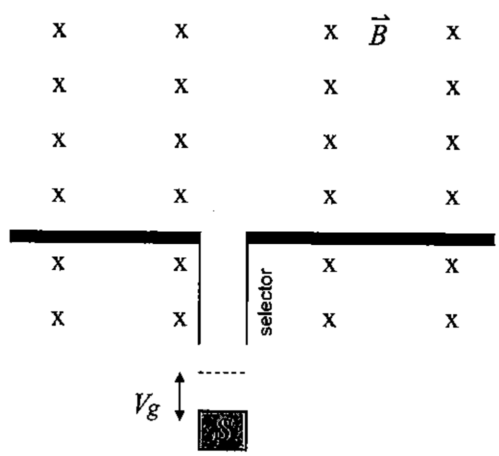

Figure 20

1. A mass spectrometer design has the following components: Positive ions of charge q and mass m are formed at a source S and accelerated through a potential difference V_g. The ions pass through a grid and into a velocity selector where there exists a magnetic field B, as shown in the figure, and an electric field. When the charges leave the selector, they enter a region where the same magnetic field is present, but there is no electric field. Respond to the following in terms of q, m, V_g, and B.

   (a) Determine the speed v_0 of the charges as they pass through the grid if they were initially at rest as they left the source.
   (b) Sketch the path of the charges after they leave the selector.
   (c) Determine the radius of the path.
   (d) Charges leaving the source may have nonzero speeds. What electric field, magnitude, and direction must exist in the selector to ensure that only the charges with v_0 leaving the grid will pass undeflected through the selector?

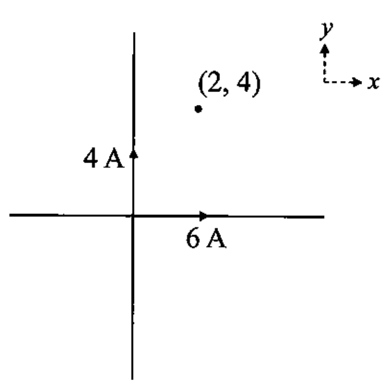

Figure 21

2. Two wires, carrying currents of 4 A and 6 A respectively, are oriented perpendicular to each other and cross without electrical connection at the origin.

   (a) Determine the magnetic field magnitude and direction at the point (2, 4).
   (b) An electron passes through this point, moving with a speed of $3 \times 10^5 \frac{\text{m}}{\text{s}}$ toward the 4 A wire ($-x$ direction). Find the magnitude and direction of the force on the electron.

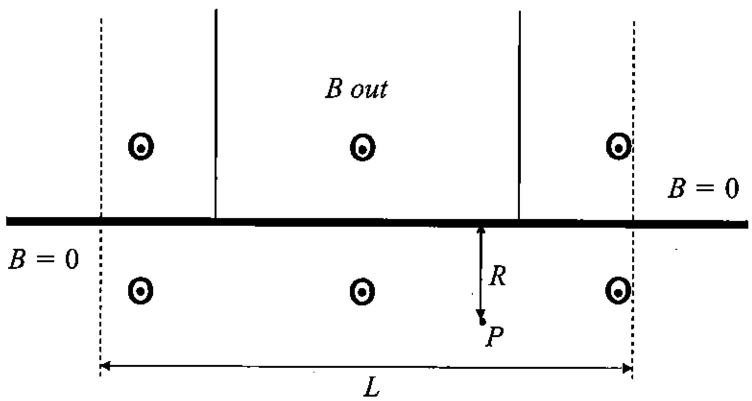

Figure 22

3. A long wire of mass m carrying current is suspended by two support cables above the floor in a laboratory. The two support cables are placed equally to the left and right of the wire center of mass. A magnetic field $\vec{B}$ of constant magnitude directed out of the paper exists in a region of length L as shown in the figure.

   (a) Find the magnitude and direction of the current that will ensure that the tension in the support cables is 0.
   (b) If the current is reversed, what will the tension in the cables be?
   (c) With the current as in (b), a positive charge q enters the region moving to the right with speed v through point P a distance R from the wire. Find the magnitude and direction of the force exerted on the charge.

Answers and Explanations

1. The answer is A. The right-hand rule for $\vec{v} \times \vec{B}$ gives a direction down, but since the electron is negative, the force is up.

2. The answer is A. The drift velocity of the charges is out of the page, so $\vec{v} \times \vec{B}$ is up. Since current is assumed to be the flow of positive charge, this is the answer.

3. The answer is C. The magnetic force is qvB directed to the left, so the electric force must equal this and point to the right. Since the charge is positive, this is the field direction as well. For the magnitude, you have

$$qvB = qE \Rightarrow E = Bv$$

4. The answer is B. The field created by either wire is directed into or out of the paper at any of the points, so D and E would yield 0 force. The fields created by each current are directed out of the paper for regions between the wires, so they reinforce each other in this region. At P_3, the two contributions oppose each other, and the point is also farther away from the right-hand current. This means that only A or B could be correct. The stronger total field occurs at P_2, as you can see:

$$B_2 = \frac{\mu_0 i}{2\pi}\left(\frac{1}{\frac{R}{2}} + \frac{1}{\frac{3R}{2}}\right) = \frac{\mu_0 i}{2\pi}\frac{8}{3R}$$

$$B_1 = \frac{\mu_0 i}{2\pi}\left(\frac{1}{R} + \frac{1}{R}\right) = \frac{\mu_0 i}{2\pi}\frac{2}{R}$$

5. The answer is C. The equation is $T = \frac{2\pi m}{qB} \cong \frac{2\pi(10^{-30})}{(10^{-19})(10^{-3})} \cong 10^{-8}$ s. The exact answer is 3.5×10^{-8} s.

6. The answer is D. The force on either wire is given by

$$F = k'\frac{I_1 I_2}{d}L$$

where L is the length of a wire. Doubling each current and doubling the separation causes F to change by a factor $\frac{(2)(2)}{2} = 2$, so the force doubles. Similar reasoning for the other choices shows that all three will double the force.

7. The answer is D. Referring to figure 16b, the right-hand rule tells you that the force on the segment carrying current out of the page is to the right, while the force on the segment carrying current into the page will be to the left. These two forces produce a torque that tends to cause clockwise rotation.

8. The answer is E. Since the velocity has components both parallel and perpendicular to the field, it will drift down the field lines as it circles them. This is a helix with axis along the field, the y-axis.

9. The answer is C. Using the long wire right-hand rule, you find that both wires create a field that points out of the paper in this region. Thus, every point in the region has a field magnitude that is the sum of the magnitude of the field from each wire. The field may point out at points in regions B and D as well, but the magnitude of the field will be the difference of the two contributions and thus smaller than in region C.

10. The answer is B. From the right hand rule for force you can see that both particles deflect in the same direction. Since they each move in a circle, they will collide when they reach the y-axis. As a result they will have traveled $\frac{1}{2}$ of a period before colliding.
The period is $T = \frac{2\pi m}{qB}$, so B follows.

FREE RESPONSE

1. (a) The kinetic energy gained as the charges move to the grid will equal the potential energy lost.

$$\frac{1}{2}mv_0^2 = qV_g \Rightarrow v_0 = \sqrt{\frac{2qV_g}{m}}$$

(b) The charges will execute a semicircle as they leave the selector, bending in a counterclockwise sense.

(c) Using the centripetal force relation (Newton's second law), you have

$$qv_0B = m\frac{v_0^2}{R} \Rightarrow R = \frac{mv_0}{qB} = \sqrt{\frac{2mV_g}{qB^2}}$$

(d) As the charges move through the selector, the magnetic force qvB pushes them to the left. If you want the charges moving with speed v_0 to be undeflected, you must introduce an electric field directed to the right with magnitude satisfying

$$qv_0B = qE \Rightarrow E = v_0B$$

2. (a) Use superposition. Find the field due to each wire, using the long wire formula. For the 4 A current,

$$B = (2 \times 10^{-7})\frac{4}{2} = 4 \times 10^{-7}\text{ T directed into paper}$$

For the 6 A current,

$$B = (2 \times 10^{-7})\frac{6}{4} = 3 \times 10^{-7}\text{ T directed out of paper}$$

The net field is then $B_{net} = 1 \times 10^{-7}$ T directed into the paper.

(b) The electron is moving at right angles to the field, so the magnitude of the force is

$$F = qvB = (1.6 \times 10^{-19})(3 \times 10^5)(1 \times 10^{-7}) = 4.8 \times 10^{-21}\text{ N}$$

Since $\vec{v} \times \vec{B}$ is directed down, the negative electron is force up in the $+y$ direction.

3. (a)

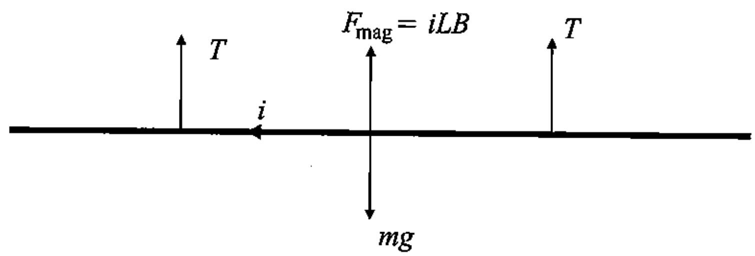

Figure 23

If the current flows to the left, the magnetic force will be directed up. Since there is no acceleration, Newton's second law gives

$$netF = 2T + iLB - mg = 0$$

If $T = 0$, then $i = \frac{mg}{LB}$

(b) Now the magnetic force is down, so the second law gives

$$netF = 2T - iLB - mg = 0 \Rightarrow T = \frac{1}{2}(iLB + mg) = mg$$

(c) The field at point P due to the wire is directed out with magnitude

$$B_w = k'\frac{i}{R} = k'\frac{mg}{LBR}$$

The charge will experience the total field due to the wire and the field $\vec{B}$. The two fields are in the same direction at P, so

$$B_P = B + B_w = \mathrm{B} + k'\frac{mg}{LBR}$$

The positive charge is moving at right angles to this field so it feels the maximum force which will be directed down.

$$F = qvB_p = qv\left(B + k'\frac{mg}{LBR}\right)$$